ATTACHMENT F

SEDIMENT COMPATIIBILITY ANALYSIS

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SEDIMENT COMPATIBILITY ANALYSIS

Brevard County Shore Protection Project – North Reach
Brevard County, Florida
Permit No: 0134869-002-JC
Permittee: Brevard County (Natural Resource Management Office)

April 21, 2014

This paper summarizes sediment grain size data representative of the native beach profile along the Brevard County, FL ocean shoreline and compares the sediment with that available from offshore sand borrow sources at Canaveral Shoals I (CS-I) and Canaveral Shoals II (CS-II). Composite grain size distributions of the native beach and borrow area materials are utilized to formulate overfill ratios to evaluate textural differences. Data utilized in this paper reflect prior investigations and experience associated with the native beach sediment, offshore sand borrow areas, and material previously placed to the beach from previous beach nourishment projects.

A. Project Description

The project will place beach-compatible sand fill along up to 9.8 miles of Atlantic Ocean shoreline along Brevard County, Florida, located between Florida Dept. of Environmental Protection (FDEP) reference monument locations R1 and R54.5. This shoreline comprises the North Reach segment of the Brevard County Federal Shore Protection Project.

The source of sand for the project renourishment shall be one or both of the Canaveral Shoals I and Canaveral Shoals II offshore borrow areas (to be determined at the time of construction), located in State and Federal waters, respectively.

The North Reach project segment was initially constructed between November 2000 and May 2001, during which approximately 3.1 million cubic yards were placed from the CS-II offshore borrow area via a nearshore rehandling area. The project was renourished in March-May 2005 with approximately 754,600 cubic yards placed from the CS-II offshore borrow area via direct hopper dredge pump-out. The project was renourished again in Feb-Apr 2014 with approximately 1.1 million cubic yards placed from the CS-II offshore borrow area via direct hopper dredge pump-out. All project construction events were contracted by the U S Army Corps of Engineers, Jacksonville District.

B. Native Beach Characteristics

The native beach material of the North Reach project area is a fine to medium grain sand with variable carbonate and coarse shell content. To specifically identify the characteristics that define the native beach sediment along the Brevard County shoreline, a variety of physical

samples collected between 1971 and 2001 along various locations and depths of the beach were collected. The geotechnical data from these samples are organized and presented in Olsen Associates' (OAI, 2002) post-construction physical report of the 2001 Federal Shore Protection Project - North Reach and Patrick Air Force Base (PAFB). From this collection of data, composite grain size curves at different vertical portions of the beach profile were generated. These curves are presented as **Figure 1**.

Native beach sediment characteristics are also described north of Port Canaveral along the Cape Canaveral Air Force Station (CCAFS) shoreline. The natural "native" sediment of this beach – which is unaffected by beach fill placement -- is described by various core boring and grab samples collected from the 1970's through 2003.[1] **Figure 2** displays the median grain size (d_{50}) with respect to the seabed elevation of each sample characterizing this natural beach.

As the two figures clearly show, coarser sand is found along the upper dry berm portion of the beach, while finer sand exists along the deeper portions of the seabed. The median grain size of sand on the dry berm is roughly 0.34 mm, while the offshore subtidal portion is about 0.14 mm (less than half the median grain size of the dry berm).

Listed below are the sediment characteristics of the native beach determined from this investigation.

- The median grain size of the native beach ranges between 0.1 and 0.6 mm (sub-tidal to berm, respectively); with a typical composite-profile median grain size of about 0.15 to 0.35 mm, more or less, and mean composite-profile grain size of about 0.25 mm.
- The median grain size of the native beach berm is about 0.35 mm ($\pm$0.1 mm standard deviation). Grain size and coarse shell content can vary significantly along the beach, with some areas of the berm frequently dominated by all sand or all shell lag.
- Samples of the native beach exhibit carbonate fractions ranging from 16% to 54%, with a typical (average) value on the order of about 40%.
- The native sand color varies with shell content, but generally ranges from about 10YR 6.5/1 to 7.5/1 (wet), and from about 10YR 7/1 to 8/1 (dry). This ranges from medium to light gray (wet), or light to very light gray (dry).

[1] Sources vary: core boring, split-spoon and grab-samples collected by USACE, Morgan & Eklund, AMEC, and Olsen Associates, Inc. (c. 1970's – 2003)

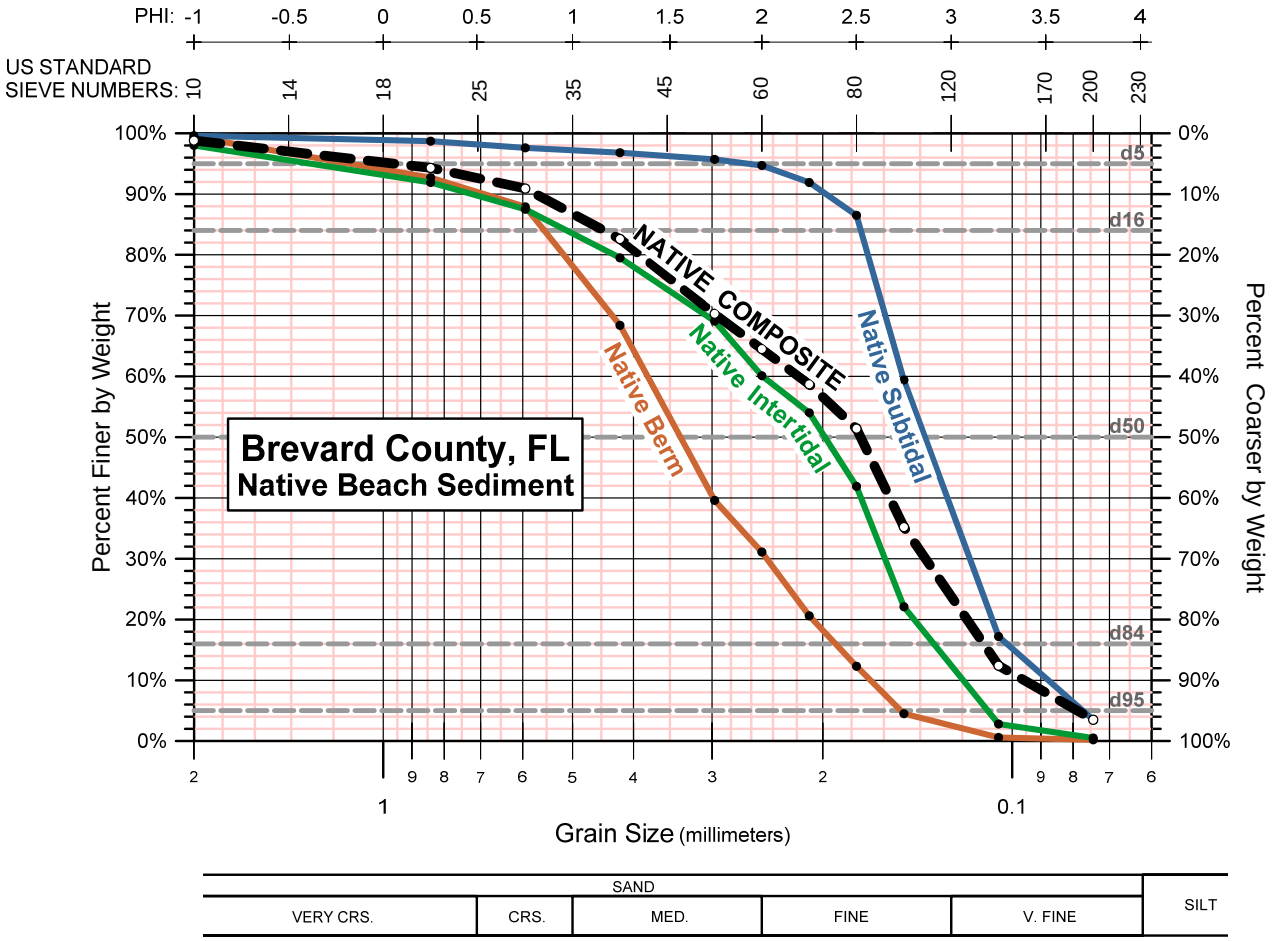

Figure 1: Native beach composite grain size curves at different vertical portions of the Brevard County, FL shoreline. Physical sediment samples were collected between 1971 and 2001 and presented in OAI (2002).

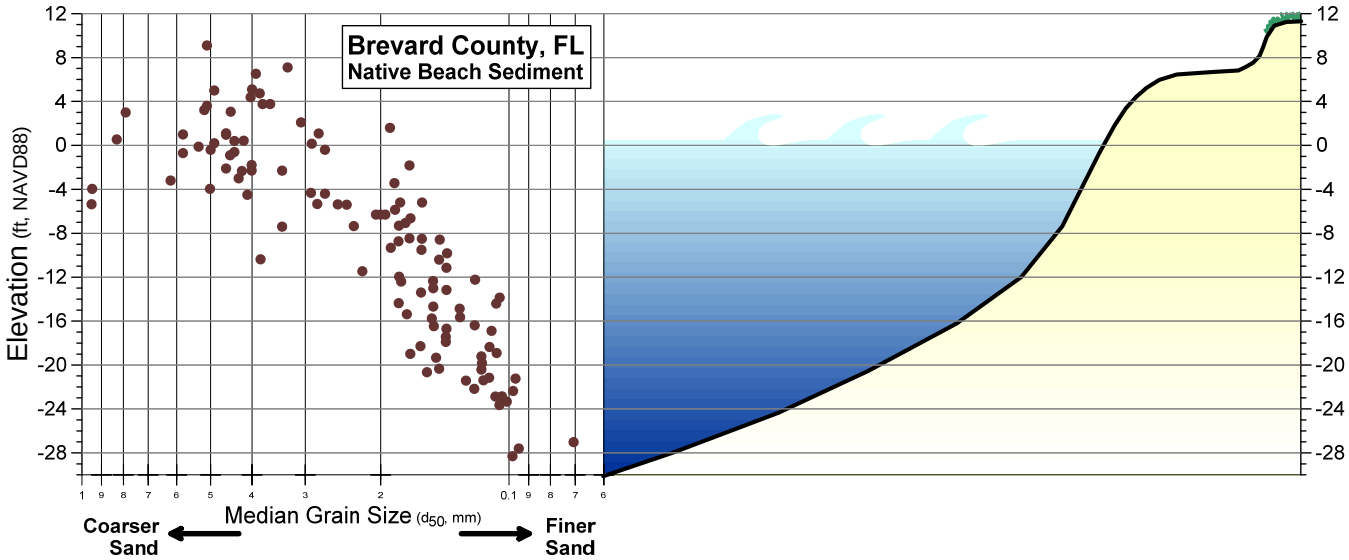

Figure 2: Brevard County native beach median grain size (d_{50}) with respect to the seabed elevation of each sample. Samples were collected along the CCAFS shoreline by various investigations (c. 1970's – 2003).

C. Sediment Borrow Sources.

The offshore borrow sites for this project include the Canaveral Shoals I (CS-I) and Canaveral Shoals II (CS-II) borrow areas, in State and Federal O.C.S. waters, respectively. [A third source, Space Coast Shoals II (SCS-II), was utilized in 2002 for construction of the South Reach project segment, and it is no longer available.

Both the CS-I and CS-II borrow areas are permitted for adjacent shore protection projects, including the South Reach and Mid Reach of the Brevard County Shore Protection Project, and Patrick Air Force Base. Both borrow areas were previously investigated and developed through evaluation of Vibracore and sediment grain size data.

To-date, two different fill sources have been used for modern, large-scale sand nourishment along the Brevard County North Reach shoreline: (1) sand bypassing from CCAFS and (2) offshore sand from Canaveral Shoals II (CS-II). See **Figure 3** for location map. Use of these two sources derives from two distinct and separate federal authorities: the first from the Canaveral Harbor Sand Bypass project authorized as part of the Canaveral Harbor Federal Navigation Project, and the latter through the Brevard County Shore Protection Project. Beach fill along Patrick AFB derives from both sources, though principally the former. The Canaveral Shoals I (CS-I) site has not yet been used.

Through sand bypassing activities, approximately 3.4 million cubic yards (Mcy) of material have been placed along the 2.5 miles of shoreline immediately south of Port Canaveral since early 1995.[2] This consisted of four major sand bypassing events: 1) SB-I in 1995, 2) SB-II in 1998, 3) SB-III in 2007 & 4) SB-IV in 2010.

The CS-II borrow area has been previously utilized on at least nine occasions, from 2000 through 2014 -- for initial construction and subsequent renourishments of the South Reach, North Reach, and Patrick AFB beach fill projects. Nearly 5.64 Mcy of material have been placed along the North Reach and Patrick AFB -- approx. 4.8 Mcy to the North Reach[3] and 0.9 Mcy to PAFB. Another 3.4 Mcy of sand from CS-II has also been placed along the Brevard County South Reach (no sand bypass material placed along the South Reach). In total, over 9.0 Mcy of material have been placed along the Brevard County beaches from CS-II. Material from this borrow area has proven to be consistent in quality and beach compatibility, as demonstrated by previous physical and environmental monitoring since 2001. The material dredged from the borrow area conformed very closely to that indicated by the original Vibracore and geotechnical data.

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[2] This does not include two bypassing projects that involved excavating material from the CCAFS dry berm and trucking it to the PAFB shoreline to be used as dune fill: 1) approx. 50,050 cy in 2011, and 2) approx. 17,000 cy in early 2014.

[3] The 4.8 Mcy volume includes material place from the Corps' 2014 FCCE Post-Sandy North Reach Renourishment currently under way at the time of this writing -- projected volume placement estimate is 1.1 Mcy to the North Reach.

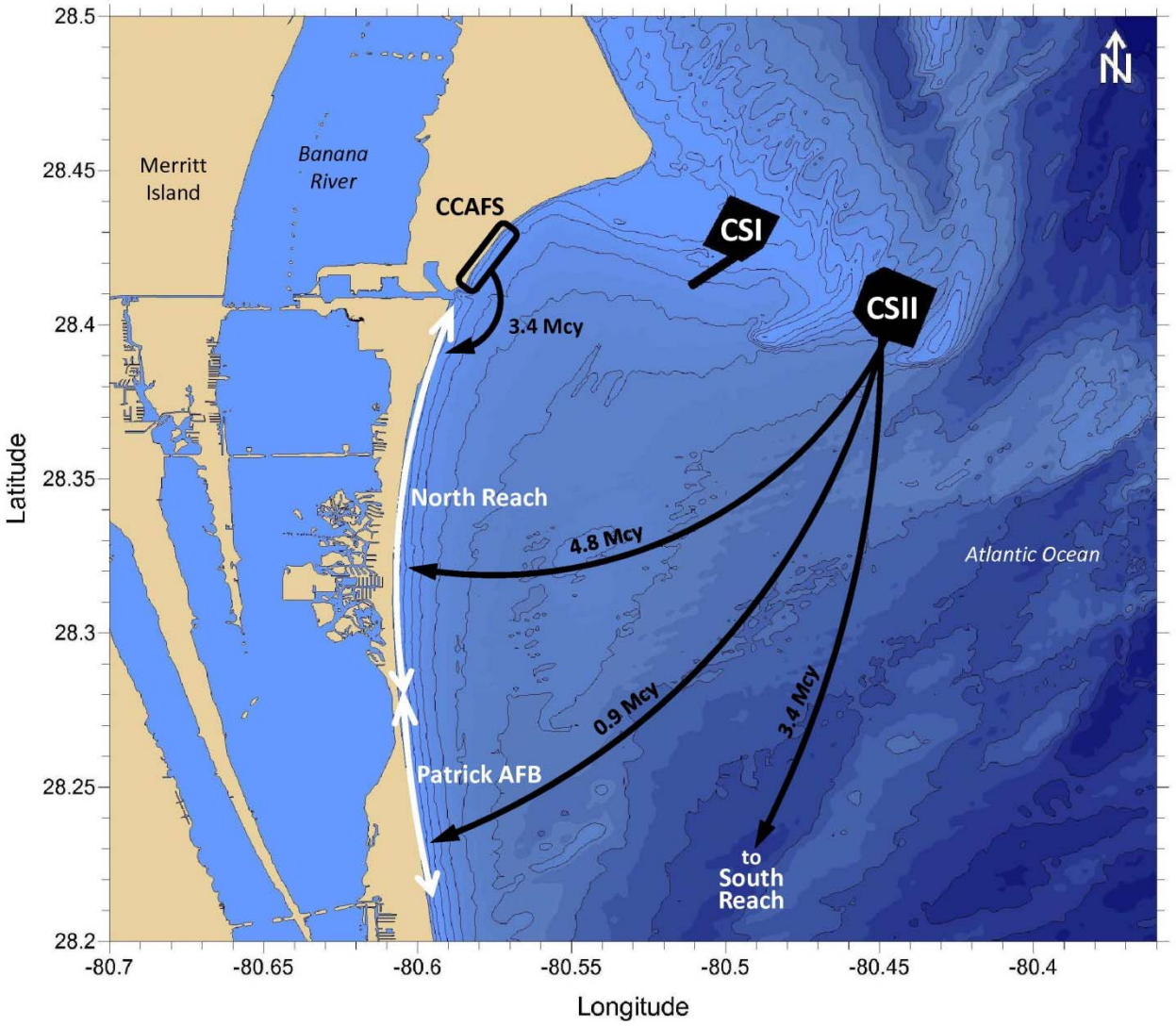

Figure 3: Location map of fill sources used for large-scale contemporary sand nourishment on the Brevard County beaches since 1995: (1) sand bypassing from CCAFS, (2) offshore sand from Canaveral Shoals II (CS-II), and (3) CS-I (yet to be used). Material from CS-II has been used for beach nourishment at Patrick AFB and Brevard County's North and South Reaches. A total of more than 9.0 Mcy from CS-II have been used as beach nourishment in the County. The CS-I site is currently permitted for use, but has yet to be used.

Upland borrow sources have been used for limited-scale dune restoration along the Mid-Reach and South Beaches shorelines in Brevard County, in 2005 through 2009. Standards for establishing and assuring the quality of material from upland sources, for the purposes of small-scale truck-haul beach fill, have been successfully developed by the Permittee (Brevard County, Natural Resource Management Office) through these prior dune-restoration works. The use of sand from upland borrow sources is not currently anticipated along the North Reach project area.

Figure 5 displays the composite grain size curves of the two sand sources used for large-scale sand nourishment on Brevard County North Reach beaches (offshore sand from CS-II and bypassed sand from CCAFS). Canaveral Shoals I, which has yet to used, is also displayed. The Brevard County native sand curves are also plotted for reference. The figure shows that the grain size distribution of the sand bypass sediment lies between the native intertidal and native subtidal sizes – while the sand from Canaveral Shoals II matches closely with the native berm.

Figure 6 displays the median size (d_{50}) range of the two beach fill sources. The shaded portions, depicting each source's respective range of median grain sizes, are plotted atop the native median sand sizes for reference.

Two values are displayed in Figure 5 representing "Sand Bypassing": (1) Sand Bypassing I & III (in 1995 & 2007) and (2) Sand Bypassing II & IV (1998 & 2010). The different median grain size of these bypassing events is due to excavated at different elevations on the CCAFS beach profile. In general, SB-II & SB-IV excavated closer to shore and at higher elevations, and thus bypassed coarser sand than SB-I & SB-III.

Figures 4 and 5 illustrate that both the Sand Bypass and Canaveral Shoals sand are compatible with the existing beach – both fall within the range of naturally occurring sands across the beach. The Canaveral Shoals sand closely matches the native sediment on the dry beach and near the waterline -- while the Sand Bypassing material more closely matches the subtidal native sediment at elevations of -4 to -20 ft NAVD88.

Because of the finer sand placed from bypassing, the beach following bypassing events typically erode quicker and persistently scarp near the wave uprush line. **Figure 4** shows an example of scarping following SB-III in 2008. Also, the sand bypass material persistently compacts more than the native or CS-II sand. Beach scarping and compaction are concerns for marine turtles nesting on the beach. These concerns are addressed after placement of bypassing sand by tilling and regularly knocking down scarps for several years after construction.

Figure 4: Escarpment along sand bypass fill area one year following Sand Bypass III in completed in 2007.

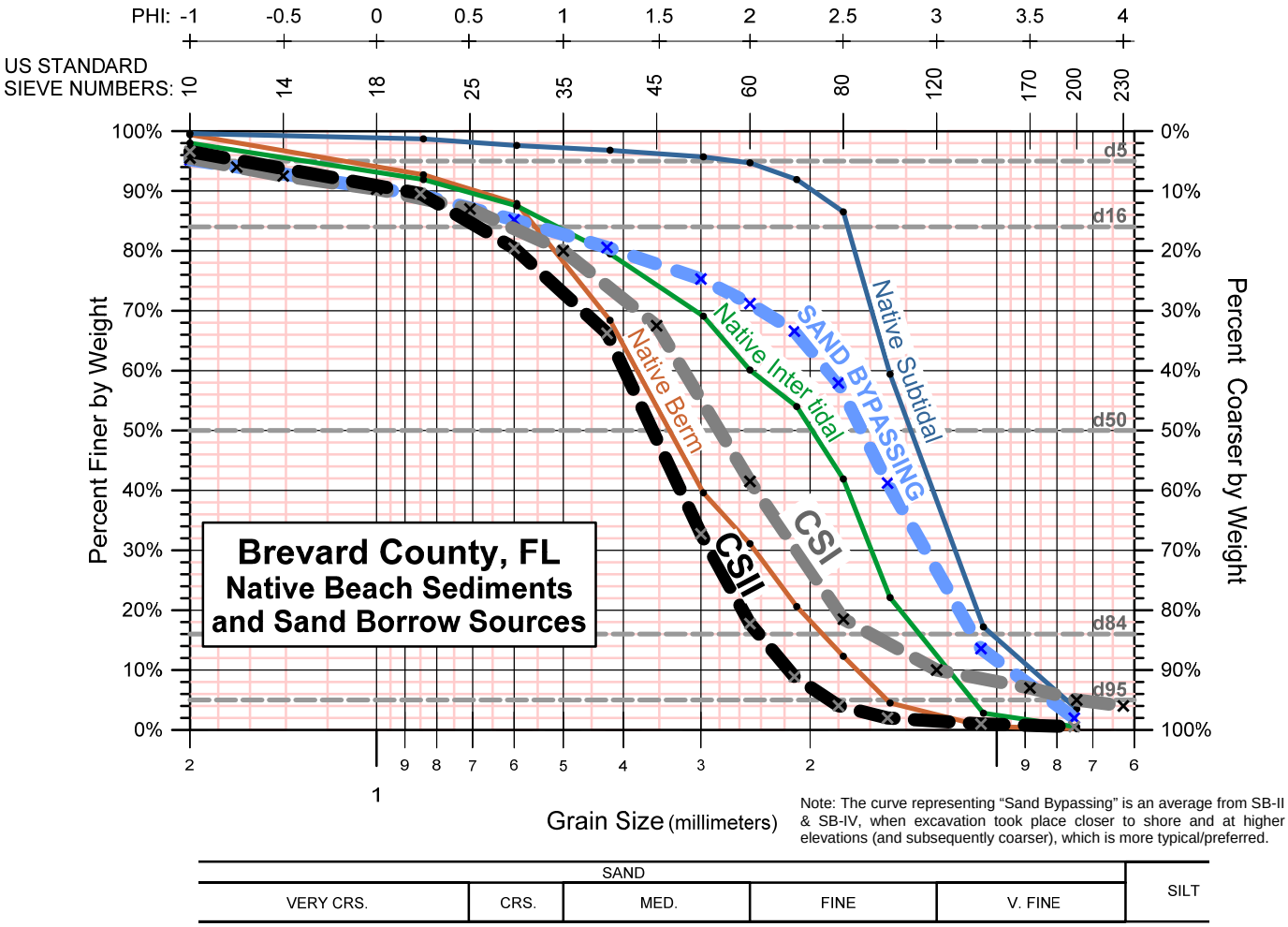

Figure 5: Composite grain size curves of native Brevard County sand and fill sources: Sand Bypassing and Canaveral Shoals II (CS-II) have been previously used for large-scale sand nourishment on Brevard County beaches. CS-I has yet to be used.

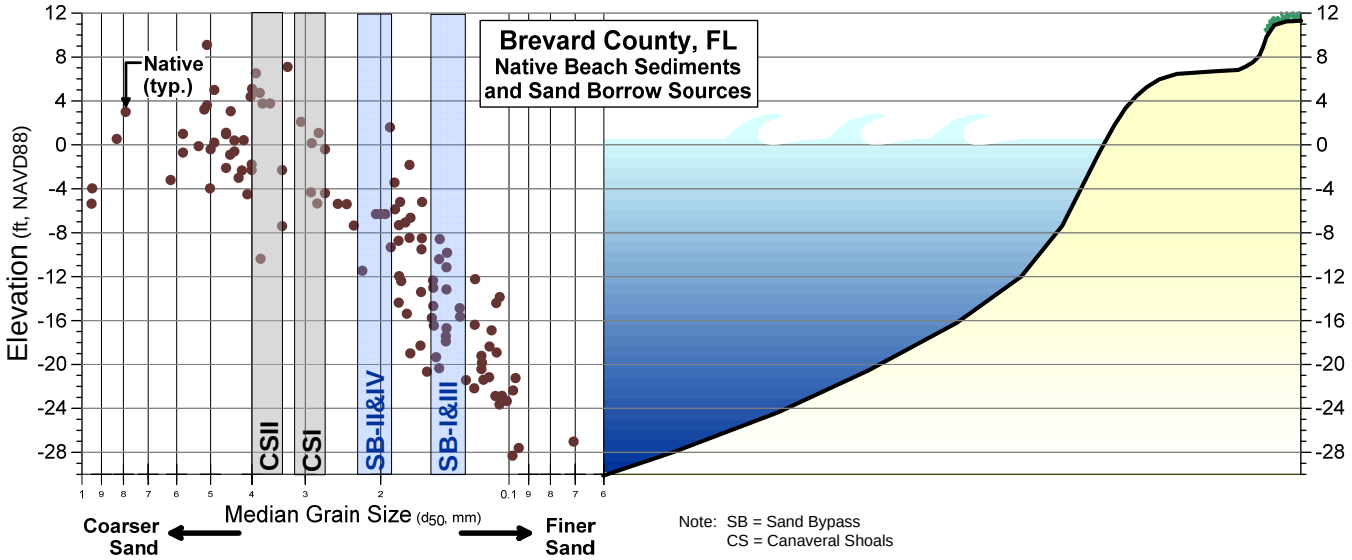

Figure 6: Median grain size (d_{50}) of native Brevard County sand (brown dots) compared to that of the beach nourishment fill sources previously used for large-scale sand nourishment on Brevard County beaches (vertically shaded segments).

The median grain size of the CS-II borrow area ranges from about 0.3 to 0.4 mm (about 0.34 mm on composite-average). The mean grain size typically ranges from about 0.34 to 0.48 mm (three-point mean), but may locally vary between about 0.3 and 0.60 mm. Fine sediment content is low, typically less than 2% finer than the #200 and #230 sieves. As of the most recent survey in the time of this writing (accounting for 2014 FCCE projects), there are approximately 20 million cubic yards of sand available within the permitted limits of the CS-II borrow area.

The median grain size of the CS-I borrow area ranges from about 0.18 to 0.3 mm (about 0.27 mm on composite-average). The mean grain size is about 0.33 mm (three-point average). Fine sediment content is typically less than 3% finer than the #200 and #230 sieves. There are at least 16 million cubic yards of sand available within the permitted limits of the CS-I borrow area.

Overfill Ratio

The overfill ratio is used to estimate the volume of additional sand that should be placed with the beach fill to compensate for textural differences between the borrow (fill) sediments and the native beach sediments. The Coastal Engineering Manual (CEM, 2008) provides an overview of the overfill ratio which includes methods developed by Dean (1975) and James-Krumbein (Krumbein and James, 1965; James 1974, 1975). In this study, both the Dean and James-Krumbein (J-K) overfill ratios are evaluated using the approaches outlined in the CEM (2008) and Bodge (2006).

Canaveral Shoals I and II, located in Federal waters offshore of Cape Canaveral, are investigated as potential borrow areas. Representing CS-I is grain size data from original core composites investigated as part of the Brevard County Shore Protection Project Feasibility Report (USACE 1996). Representing CS-II is grain size data from as-built samples collected as part of the 2000/01 and 2005 North Reach Federal Shore Protection Project (OAI, 2013). **Table 1** represents grains size distributions utilized for overfill-ratio formulation.[4] The grain size distributions found in the tables are identical to those displayed in Figure 1 (native) and Figure 5 (CS-I & CS-II). Listed below are the overfill ratios for CS-I and II determined from this investigation. **Figure 7** and **Figure 8** on the following pages display the graphs used to evaluate the Dean and J-K overfill ratios.

CS-I Overfill Ratio

- James-Krumbein method: 1.00
- Dean method: 1.00

CS-II Overfill Ratio

- James-Krumbein method: 1.00
- Dean method: 1.00

[4] The overall mean and standard deviation were computed using formulas outlined in the Coastal Engineering Manual (CEM, 2008).

Table 1: Grain size distributions utilized for overfill-ratio formulation (data identical to that displayed in the grain size distribution plots).

Native Beach Composite (OAI, 2002)				
Sieve	**Size (in)**	**Size (mm)**	**Size (ϕ)**	**% By Weight Coarser Than**
10	0.079	2.000	-1.0	**1.20**
20	0.033	0.841	0.25	**5.70**
30	0.023	0.595	0.75	**9.10**
40	0.017	0.420	1.25	**17.40**
50	0.012	0.297	1.75	**29.70**
60	0.010	0.250	2.0	**35.50**
70	0.008	0.210	2.25	**41.30**
80	0.007	0.177	2.5	**48.60**
100	0.006	0.149	2.75	**64.80**
140	0.004	0.105	3.3	**87.60**
200	0.003	0.074	3.75	**96.50**

Canaveral Shoals I Offshore Borrow Area (original core composite, USACE 1996)				
Sieve	**Size (in)**	**Size (mm)**	**Size (ϕ)**	**% By Weight Coarser Than**
4	0.187	4.757	-2.25	**1.00**
6	0.132	3.364	-1.75	**1.90**
7	0.111	2.828	-1.5	**2.90**
8	0.094	2.378	-1.25	**3.70**
10	0.079	2.000	-1.0	**4.50**
12	0.066	1.682	-0.75	**6.00**
14	0.056	1.414	-0.5	**7.50**
18	0.039	1.000	0.0	**9.70**
25	0.028	0.707	0.5	**13.00**
35	0.020	0.500	1.0	**20.00**
45	0.014	0.354	1.5	**32.50**
60	0.010	0.250	2.0	**58.50**
80	0.007	0.177	2.5	**81.50**
120	0.005	0.125	3.0	**90.00**
170	0.003	0.088	3.5	**93.00**
200	0.003	0.074	3.75	**95.00**
230	0.002	0.063	4.0	**96.00**

Canaveral Shoals II Offshore Borrow Area (avg of 2000/01& 2005 No. Rch as-built samples)				
Sieve	**Size (in)**	**Size (mm)**	**Size (ϕ)**	**% By Weight Coarser Than**
4	0.187	4.757	-2.25	**1.20**
10	0.079	2.000	-1.0	**3.40**
20	0.033	0.841	0.25	**10.45**
30	0.023	0.595	0.75	**19.55**
40	0.017	0.420	1.25	**33.75**
50	0.012	0.297	1.75	**67.25**
60	0.010	0.250	2.0	**82.25**
70	0.008	0.210	2.25	**91.10**
80	0.007	0.177	2.5	**95.95**
100	0.006	0.149	2.75	**98.00**
140	0.004	0.105	3.3	**99.00**
200	0.003	0.074	3.75	**99.45**

Table 2: Overfill ratio calculations using the James- Krumbein and Dean methods.

Native Beach Composite (OAI, 2002)						
	phi-05	phi-16	phi-50	phi-84	phi-95	
Grain Size Distribution	0.06	1.17	2.52	3.17	3.67	phi
Mean	2.29	phi				
Standard Deviation	1.10	phi				

Canaveral Shoals I (CSI) (original core composite, USACE 1996)						
	phi-05	phi-16	phi-50	phi-84	phi-95	
Grain Size Distribution	-0.92	0.71	1.84	2.65	3.75	phi
Mean	1.73	phi				
Standard Deviation	1.26	phi				
(Mb-Mn)/Sn	-0.50	*see Fig. 7*				
Sb/Sn	1.14					
J-K Overfill Factor (R_A)	**1.00**					
(Mb-Mn)/Sb	-0.44	*see Fig. 8 (negative values,*				
Dean Overfill Factor (K)	**1.00**					

Canaveral Shoals II (CSII) (avg of 2000/01 & 2005 No. Rch as-built samples)						
	phi-05	phi-16	phi-50	phi-84	phi-95	
Grain Size Distribution	-0.72	0.55	1.49	2.05	2.45	phi
Mean	1.37	phi				
Standard Deviation	0.90	phi				
(Mb-Mn)/Sn	-0.83	*see Fig. 7*				
Sb/Sn	0.82					
J-K Overfill Factor (R_A)	**1.00**					
(Mb-Mn)/Sb	-1.02	*see Fig. 8 (negative values, K=1)*				
Dean Overfill Factor (K)	**1.00**					

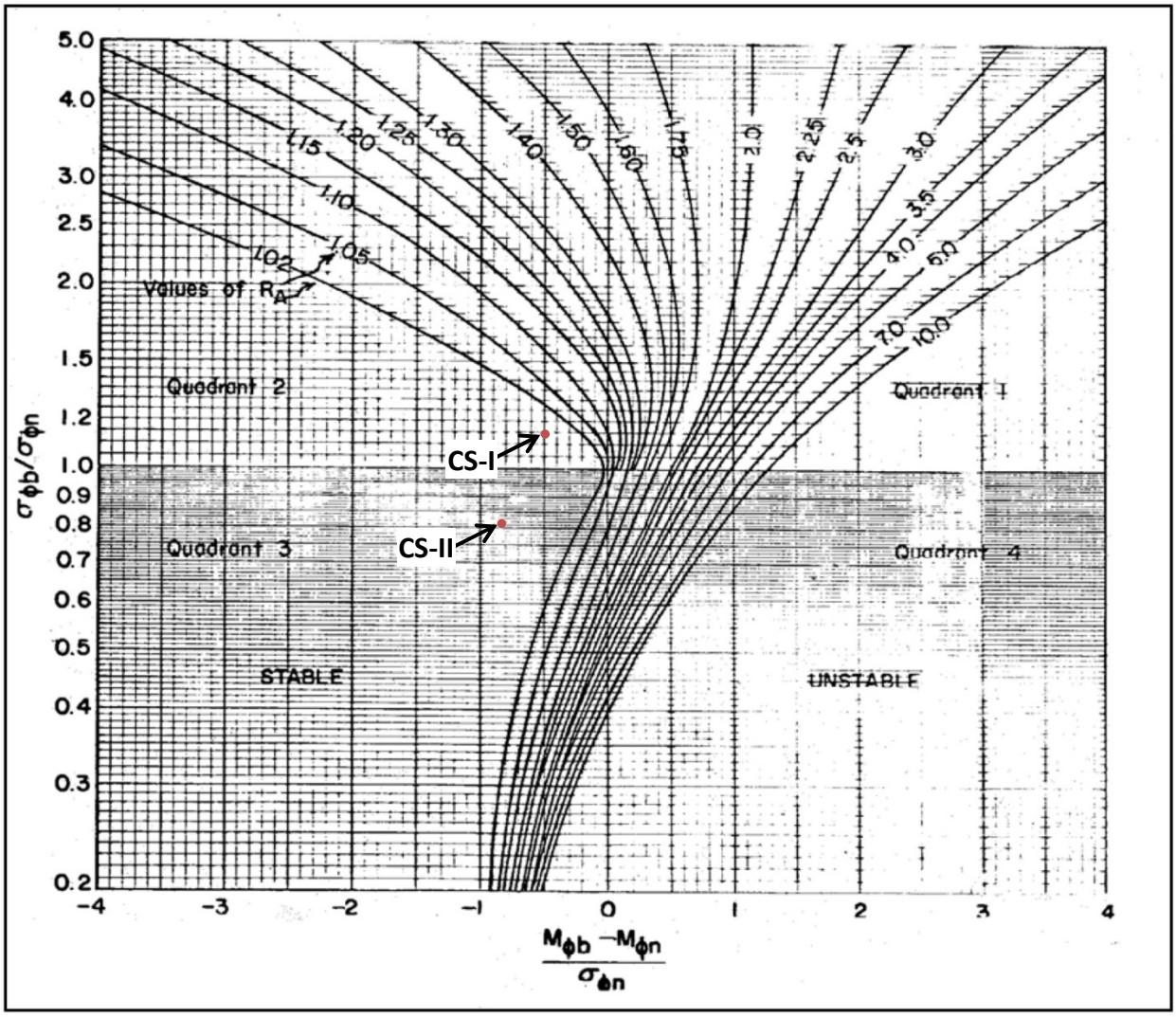

Figure 7: Isolines of the overfill ratio (R_A) for values of ϕ mean difference and ϕ sorting ratio. This graph is reproduced from the U.S. Army Corps of Engineers' Coastal Engineering manual (CEM 2008), Figure V-4-9.

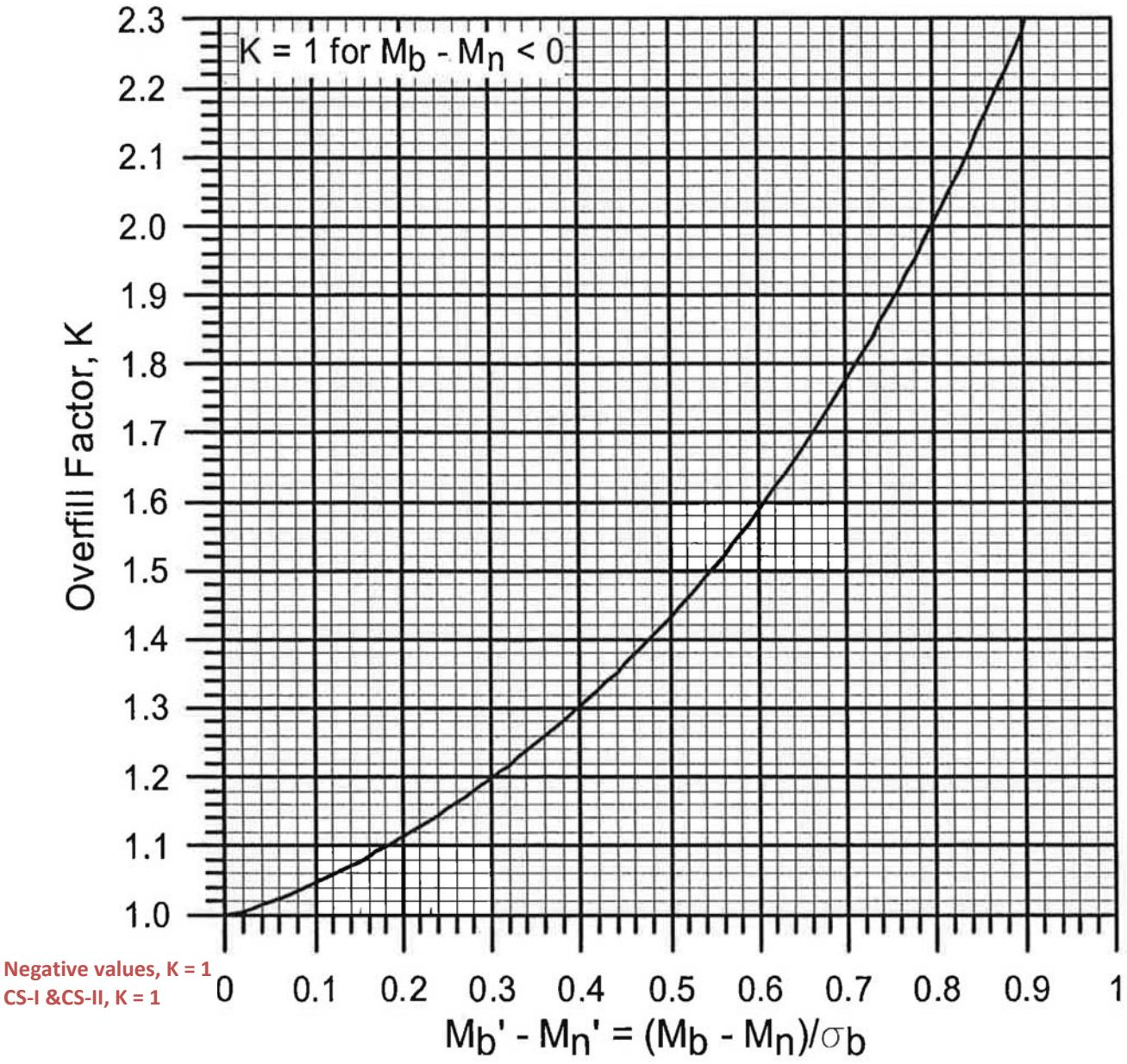

Figure 8: Dean's overfill ratio expressed as a single curve, shown for K < 2.3. This graph is reproduced from Bodge's *Alternative Computations of Dean's Overfill Ratio* (Bodge, 2006).

D. Sand Sources and their Observed Effect on the Beach (April 2013 Sampling).

An investigation was undertaken in April 2013 to assess the geotechnical status of the Brevard County beaches previously nourished by sand from bypassing and Canaveral Shoals II (CS-II). Physical grab-samples were collected in mid-April at different beach transects along the Brevard County coast, along various portions of the beach profile. Sampling locations were chosen to replicate pre-project native sampling locations, as practicable, and also to specifically investigate beach areas nourished by both sand bypassing and CS-II as well as those beaches nourished exclusively by CS-II. Most of the pre-project samples, from the 1980's through 2001, were collected by current employees of Olsen Associates, Inc.; so there is first-person familiarity with the historical and present samples. **Table 3** lists the April 2013 sand sample locations -- 41 samples were collected in total. Attached to the end of this paper are grain size distribution tables and graphs for all of the samples collected as part of the April 2013 investigation.

Grain Size Distribution Comparison

Figure 9a through **Figure 9c** display the grain size distributions of the samples collected in April 2013. Each of the figures represents the collection of samples along a different portion of the beach profile. In each figure, the samples are plotted with the native composite of the associated beach elevation. The figures show that the April 2013 sand exhibits a good match with pre-project native grain sizes (1980's-2001) at each depth regime. This result is not unexpected since both the fill sources closely match the native material.

Table 3: Physical grab-sample locations of the April 2013 geotechnical investigation. The elevations listed are roughly relative to mean sea level (MSL = -1.2' NAVD88, approx.).

Sampling Location	Location on Beach Profile					
	Berm	+3'	-3'	-6'	-9'	-12'
R7 Washington Ave	✓	✓	✓	✓	✓	✓
R20 Shepard Park	✓	✓	✓	✓	✓	✓
R28 Lori Wilson Park	✓					
R33 3rd St. North (Slater Way)	✓	Intertidal		-4	✓	
R36 1st St. South	✓	✓	✓	✓	✓	✓
R64 PAFB - Hangers	✓	✓	✓	✓	✓	✓
R120 Long Doggers	✓	✓	✓	✓	✓	✓
R125 Wavecrest/Indialantic Boardwalk	✓	✓	✓	✓	✓	✓

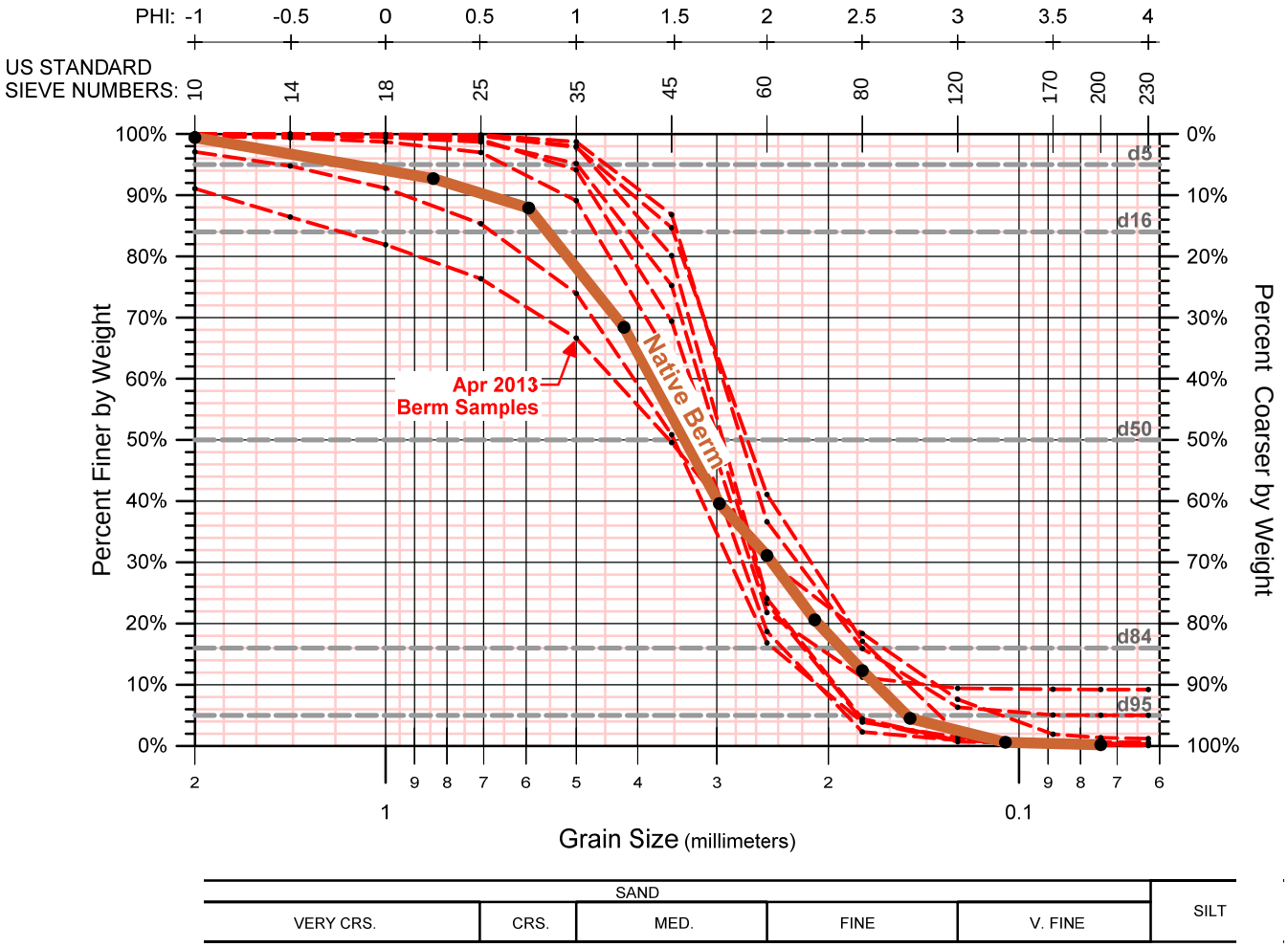

Figure 9a: Grain size distribution data for the April 2013 grab-samples collected along the upper-beach profile (berm, approx. +6.5' MSL). The April 2013 data are shown by red dashed lines. The average pre-nourishment condition is shown by the bold brown line.

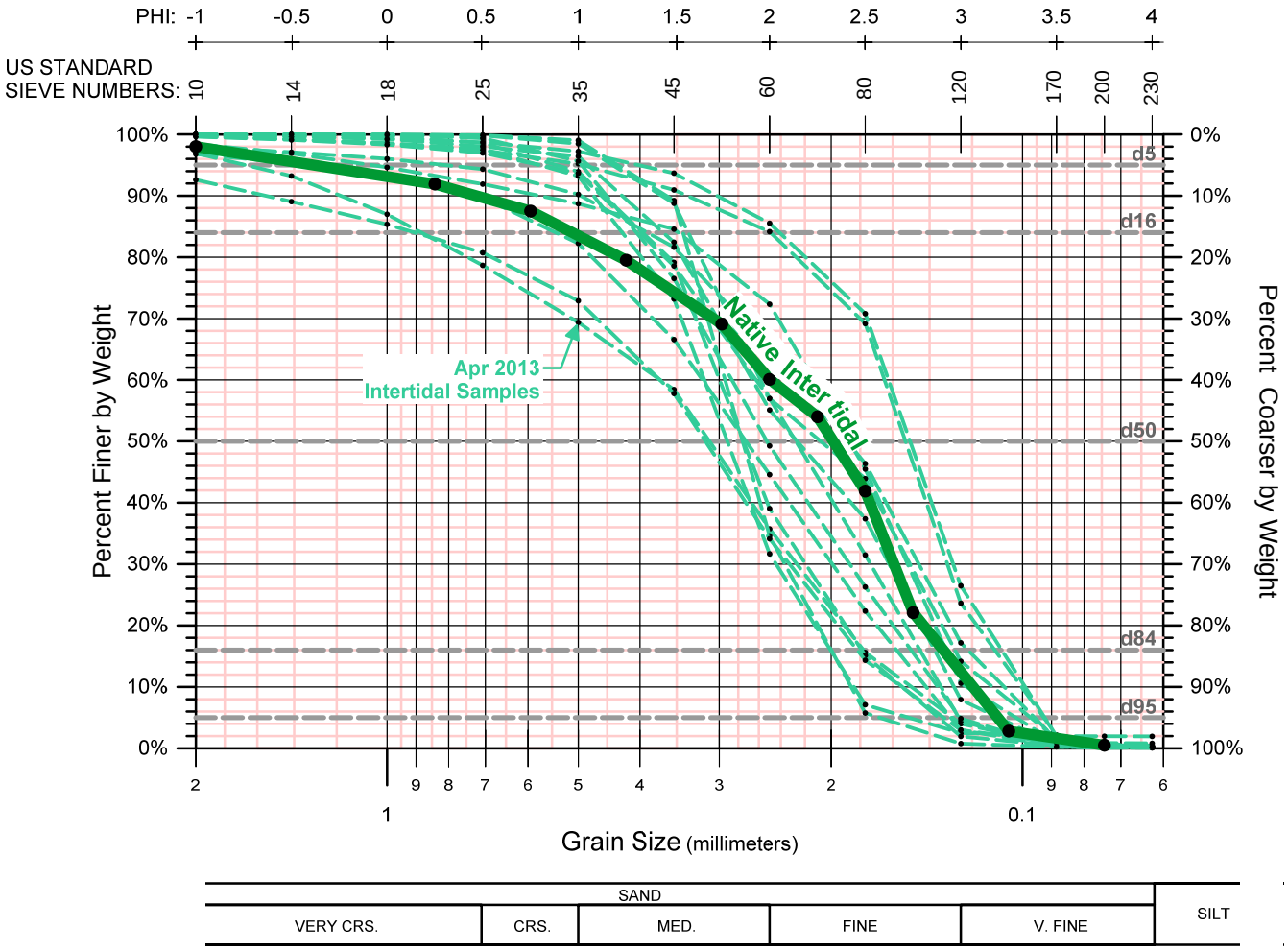

Figure 9b: Grain size distribution data for the April 2013 grab-samples collected along the intertidal zone of the beach profile (+3' and -3'). The April 2013 data are shown by green dashed lines. The average pre-nourishment condition is shown by the bold green line.

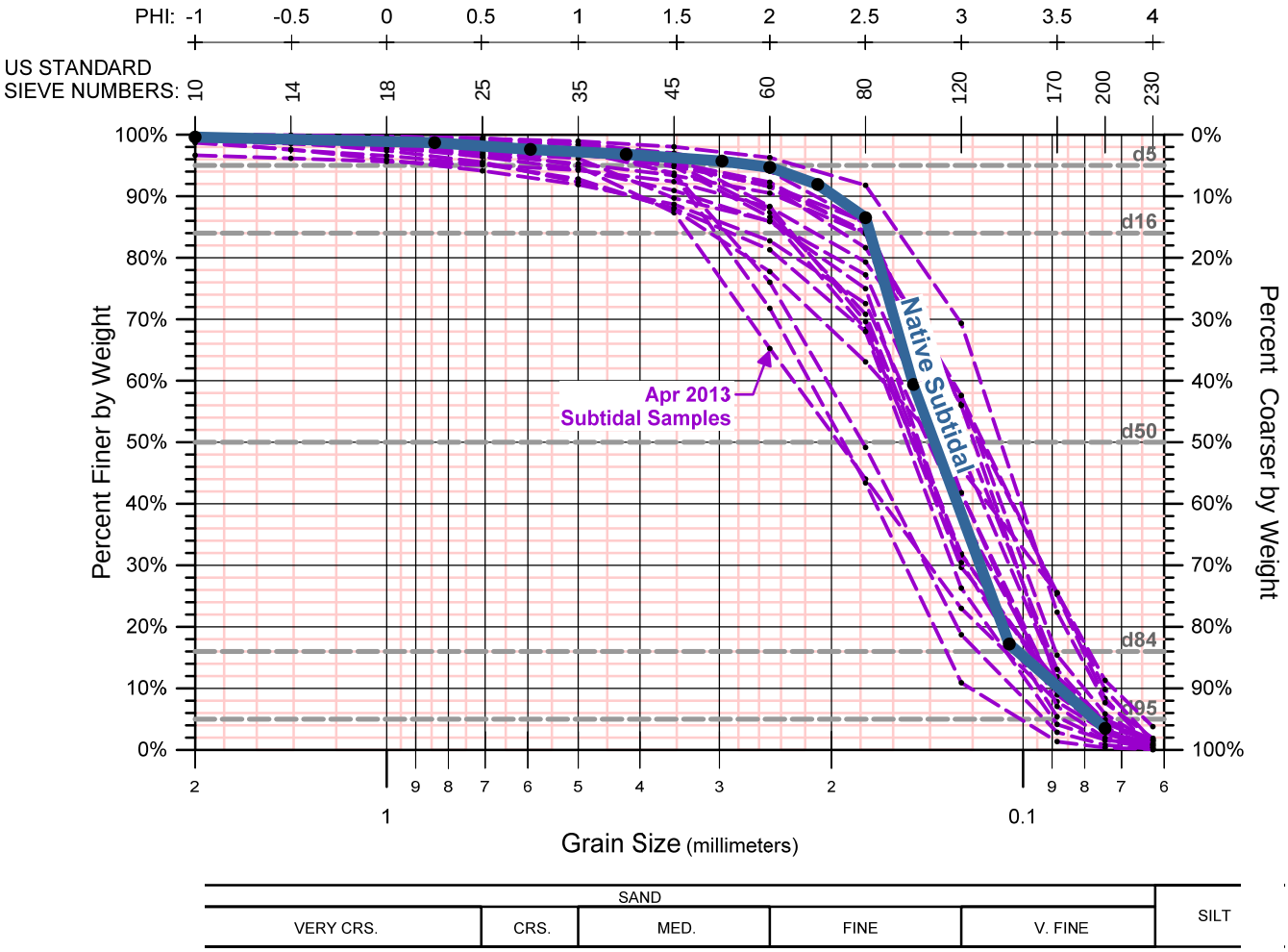

Figure 9c: Grain size distribution data for the April 2013 grab-samples collected along the subtidal zone of the beach profile (-3', -9', and -12'). The April 2013 data are shown by purple dashed lines. The average pre-nourishment condition is shown by the bold blue line.

Beach Profile Shape Comparison

This section examines how the beach profile shape has changed over the years due to sand nourishment. First, a single representative profile transect location is examined to simply and clearly illustrate beach profile changes. **Figure 3.1** displays many beach profile surveys at a single beach transect located within the Brevard County North Reach project area: R-36 near the Minutemen Cswy in Cocoa Beach. The surveys shown in red were conducted prior to contemporary beach nourishment in this area (pre-2001), and the surveys in green were conducted following the commencement of nourishment (2001 and afterward).

Figure 3.2 displays the same surveys with shading that highlights the "envelope" of beach profile variations for the pre- and post-nourishment condition at this location. The profile locations below the waterline are generally similar in the pre- and post-nourishment condition in terms of range of profile location and slope. That is, below the mid-tide waterline, the variation of the beach profile prior to nourishment (red) is similar to, and mostly overlapping, the variation of the beach profile following nourishment (green). Above the waterline, the post-nourishment

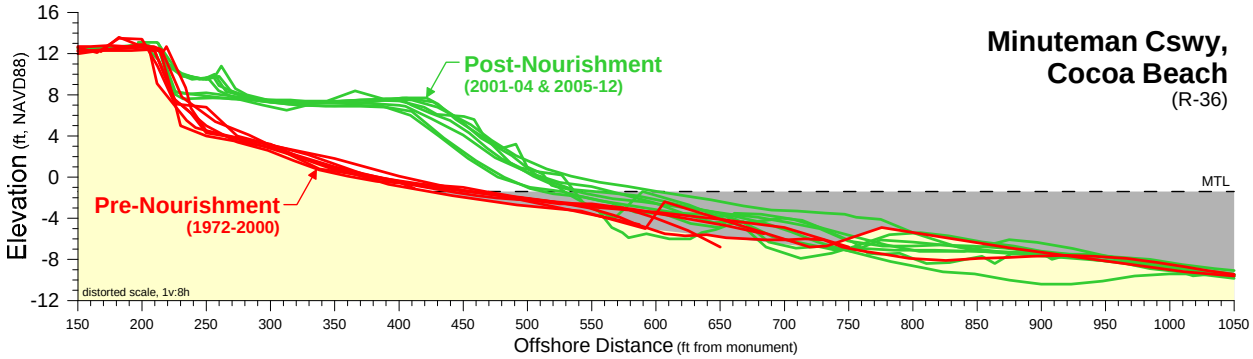

Figure 3.1: Beach profiles at a single beach transect located within the Brevard County North Reach project area.

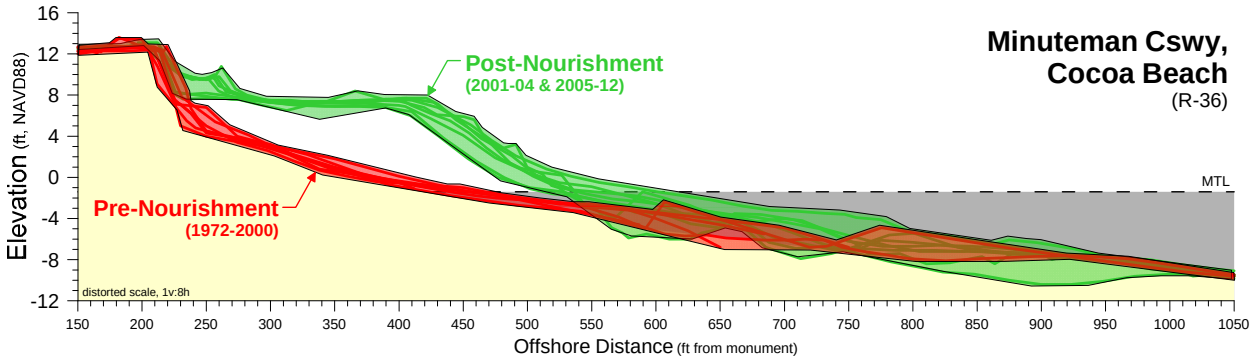

Figure 3.2: Beach profiles at a single beach transect located within the Brevard County North Reach project area. The shaded region depicts the extent of profile location for the pre- and post-nourishment condition.

profiles (green) are clearly wider and higher than the pre-nourishment profiles (red); that is, the

profiles are different above the waterline. This is, of course, by design of the project. The purpose of the project is to widen and raise the dry beach in front of the originally exposed seawalls and pre-project escarpments. In so doing, the project inherently changes the shape of the upper beach profile: from a flat, over-eroded shape inundated by high tides and storm waves and shaped by the effect of seawalls – to a more natural concave shape with beach-face, berm, and dune. In all, the post-project condition exhibits a purposefully different beach geometry above the waterline (by design) and it exhibits a similar seabed profile below the waterline, relative to the pre-project, pre-nourishment condition.

Figure 3.3 displays composite beach profiles representing the 10,000-foot shoreline segment between 3rd Street North and 11th Street South in Cocoa Beach (R-33 to R-43). A composite profile is simply an average of beach profile transects along a given segment of shoreline. The figure displays three composite profiles:
(1) immediately prior to the commencement of nourishment in 2000 (red),
(2) immediately following the most recent CS-II renourishment in May 2005 (blue), and
(3) most recent survey in May 2012, 7 years follow the 2005 renourishment (green).

As the figure shows, the composite profile 7 years following the 2005 renourishment is very similar to the post-renourishment profile. Furthermore, the offshore portions of all three composite profiles are very similar. Overall, there is little difference between the profile shape immediately following renourishment (in 2005) and that observed seven years later (in 2012). Here, the notion that the placed sand profile undergoes substantial equilibration and change after renourishment, working itself to a different or 'natural' profile, is not evident. This is not to say that the placed sand fill does not adjust or change after construction – it does, and certainly in response to storms – but, Figure 3.3 indicates that the average long-term change is not dramatic.

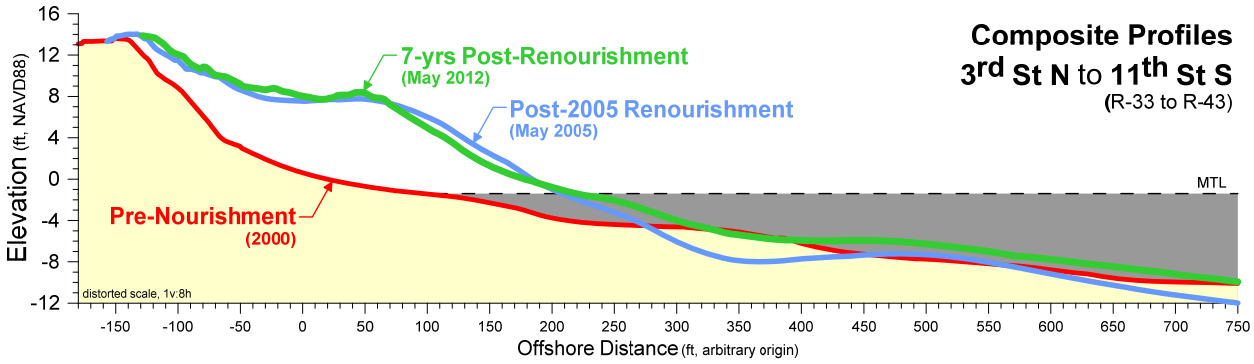

Figure 3.3: Composite beach profiles representing the 1,000-foot shoreline segment between 3rd Street North and 11th Street South in Cocoa Beach, FL. This segment of shoreline was nourished by CS-II in 200/01 and again in 2005.

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